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Module Flexibility for Single-Axis Solar Trackers

A study on FlexRail™ and other tools for addressing module changes during project design

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Executive Summary

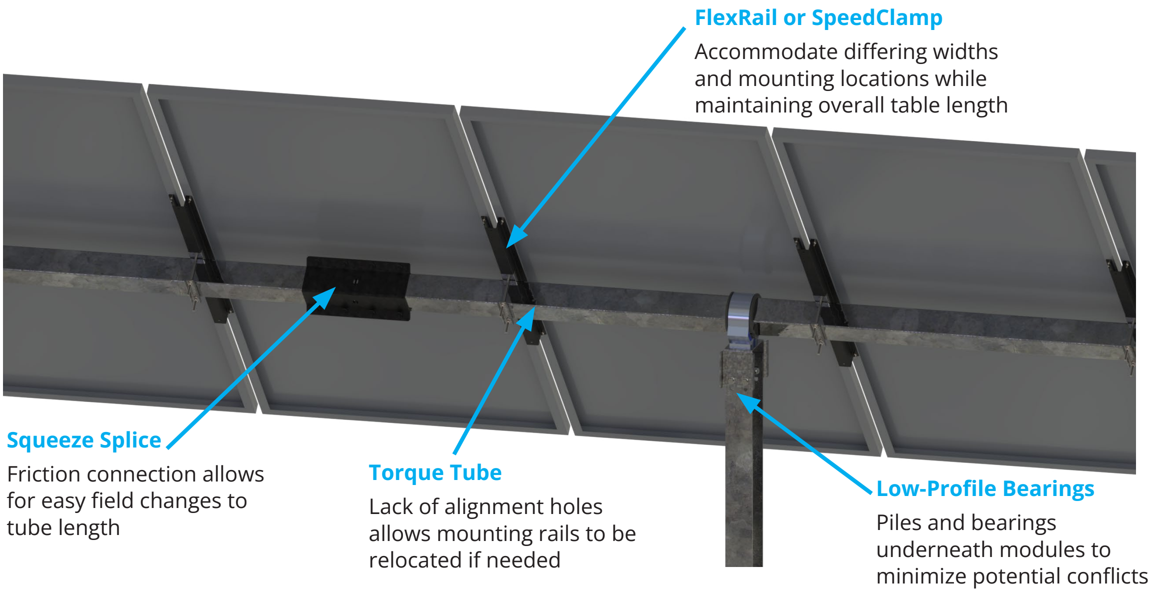
Utility-scale solar projects face growing uncertainty in PV module supply, driven by global tariffs, supply chain disruptions, and shifting price dynamics. Many projects are initially designed around a specific module, only to confront costly module changes later in development. While most single-axis tracker systems can accommodate different modules during early design, structural incompatibilities often emerge once components are manufactured, leading to delays, redesigns, and added expense. This paper highlights how tracker flexibility can preserve project economics by reducing the risks associated with late-stage module substitutions.

The analysis identifies key structural considerations that determine whether a tracker system can adapt to different modules, including tracker table length, rail design, torque tube connections, splice locations, and post configurations. Inflexible designs often force field drilling, cutting, additional pile driving, or realignment, driving up costs. In contrast, features such as clamp-based rail systems, flexible purlins, unpunched torque tubes, and low-profile bearings can provide the dimensional tolerance necessary to handle variations in module size and mounting geometry.

Using SpeedClamps, FlexRails, and other innovative designs, GameChange Solar's Genius Tracker™ offers multiple layers of redundancy to minimize financial and schedule impacts when module changes occur.

Through real-world case studies, the paper demonstrates how flexibility reduces remediation costs across different project stages, whether during early design, after tracker fabrication, or even after post installation. By building adaptability into tracker design, developers can lock in procurement earlier, hedge against supply volatility, and maintain optimal project economics. In an environment where module uncertainty is the norm, flexible tracker systems provide a strategic advantage for developers, EPCs, and investors alike.

Flexible design integrated into the Genius Tracker system



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In his role as Product Director, Nat works directly with the Business Development, R&D, and Engineering staff to facilitate collaboration and promote continued learning on products and industry trends.

Passionate about education, Nat leads internal and external workshops to both train and learn directly from clients, field installers, and internal teams around the world.

Nat graduated from Dartmouth College, with a B.Eng. in Mechanical Engineering.

1.0 Introduction

In recent years, one of the challenges facing utility-scale solar development has been the selection and availability of PV modules. Many projects are initially designed around a specific module, only to face changes later due to price shifts, shipping delays, or customs complications. These issues are further compounded by broader factors such as tariffs, global supply chain constraints, and domestic content requirements in different countries.

Most single-axis tracker providers can work with any commercially available solar module during the project design phase. The challenge comes later: once tracker components are manufactured, structural differences between designs can make switching to a different module costly. This paper highlights key tracker features that reduce the impact of module changes on installation costs. By considering these features early, developers can order trackers before finalizing module selection, preserving flexibility and reducing risk during times of market uncertainty.

2.0 Structural Considerations

The design of a single-axis solar tracker for a utility-scale solar power plant is impacted by the PV module selection in several ways, most notably including:

- Overall tracker table length
- Module rail design
- Module rail to torque tube connection
- Torque tube segment length and splice locations
- Post locations and reveal height

These features are discussed in detail below.

2.1 Overall Tracker Dimensions

The overall length of each independent structure that can rotate east-west (herein referred to as a “tracker table” or simply “tracker”) is a function of module width, module spacing, number of modules per string, and number of strings per table. If a project is considering multiple modules, the design should assume the configuration that results in the longest overall tracker.

For civil design, this is critical to determining the locations of roads. If the design ultimately changes to a smaller module, the tracker tables will still fit within the footprint allocated initially for them.

For structural design, longer table lengths result in larger torsional forces accumulating in the torque tube. This can cause the torque tube to be overstressed when changing to a PV module and stringing configuration that results in a longer table length. Similarly, longer chord lengths (i.e., the east-west dimension of the PV module) result in larger torsional forces in the torque tube. For tracker systems that use dampers or shock absorbers to stabilize the system, such as the Genius Tracker by GameChange Solar, dampers can be used to unload some of this torsional load from the torque tube, but at an additional cost.

2.1 Module Rail Design

Although there is a wide variety of module rail designs connecting PV modules to a torque tube currently employed in the market, they generally fall into one of two categories: 1) a purlin with bolts, nuts, or similar fasteners, or 2) a clamp system.

A bolt and nut-based purlin system will attach directly through the module’s pre-punched mounting holes. Different PV module manufacturers often use different mounting hole spacing, both in the width and length directions of the module. As shown in Figure 1, even modules with the same dimensions may have differing mounting hole locations.

These varying hole spacings provide two issues when changing between modules. The first issue stems from the mounting hole spacing in the length direction. Purlins designed for the 990 mm mounting holes on the left module will not be long enough to mount into the 1100 mm holes on the right module. Conversely, purlins provided for the right module will require expensive field drilling of mounting holes at 990 mm spacing to accommodate the left module.

The second issue stems from the mounting hole spacing in the width direction. Purlins are typically stamped with slots allowing for only minor width adjustment. Modules with dramatically different mounting slot spacing in the width direction result in different spacing between modules when using the same purlin design. This can result in longer tables and risk changing overall tracker dimensions as discussed in Section 2.1.

Specially designed flexible purlins, like the FlexRail™ by GameChange Solar, can be used to alleviate these dimensional constraints. As shown in Section 4.3, the FlexRail's expanded adjustment allows for multiple modules of varying dimensions to be designed on the same tracker table.

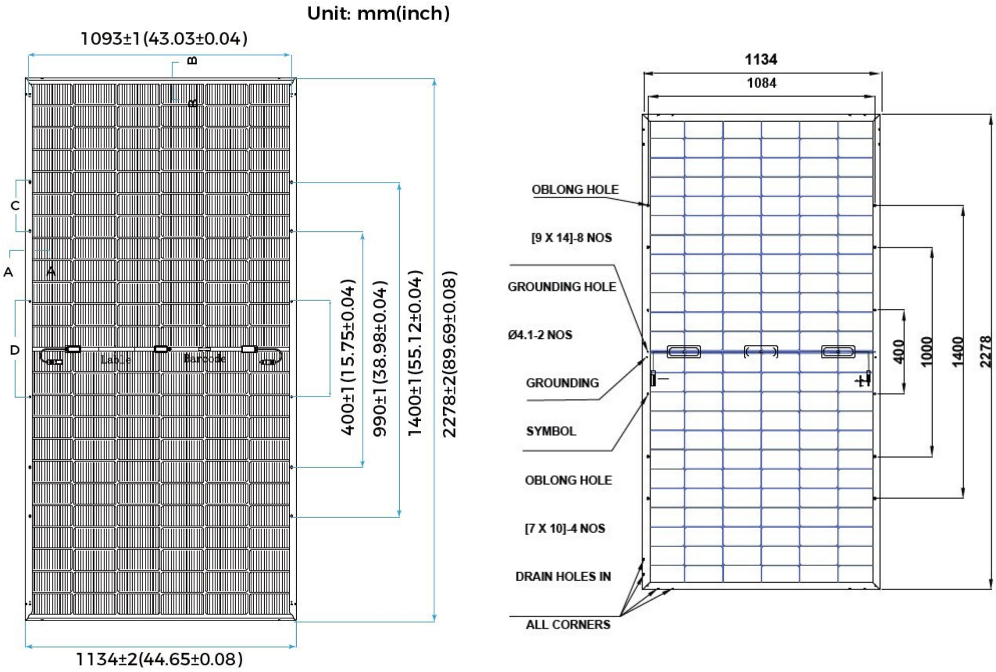

FIGURE 1:

Modules of the same size, but with different mounting hole spacing in the length direction (990 mm left vs 1000 mm right) and width direction (1093 mm left vs 1084 mm right).

Clamp systems are typically preferable for maintaining flexibility, as they avoid the variations in mounting hole locations referenced above. For example, the same 470 mm long SpeedClamp™ by GameChange Solar shown in Figure 2 can accommodate a wide variety of PV module designs regardless of mounting hole location.

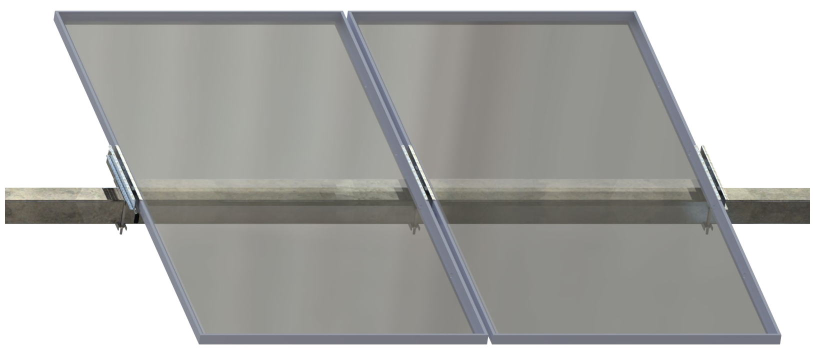

FIGURE 2:

SpeedClamp™ design connects directly to the module frame, bypassing module mounting holes.

For both purlin and clamp designs, even if the module mounting dimensions are identical, each module design's ability to withstand wind and snow loading is unique, due to module frame, manufacturing, and glass differences. Changing from a stronger to a weaker module may require lengthening of the existing clamp design or more bolted connections for a purlin design.

2.3 Module Rail to Torque Tube Connection

There are a number of methods employed by tracker manufacturers to connect the mounting rail to the torque tube. In part, these are a function of the shape of the torque tube: round, square, pentagon, hexagon, etc. Several tracker designs require alignment holes to position the mounting rail along the length of the torque tube. These alignment holes can pose challenges when evaluating a module change.

Module widths commercially available today vary from less than 1.0 m to more than 1.3 m. Even if the modules are identical in width, differences in mounting hole spacing in the width direction can result in different module spacings, as described in Section 2.2. Either a change in module width or module spacing would require adding new alignment holes to a torque tube design. Adding new alignment holes after the tubes have been processed is time-consuming and expensive. Furthermore, new alignment holes may be unacceptably close to an existing alignment hole, requiring further remediation to ensure the location has sufficient structural strength.

Several single-axis tracker manufacturers, including GameChange Solar, provide single-axis trackers that do not use alignment holes or other features in the torque tube. As such, these tracker designs are inherently more flexible for accommodating module changes.

2.4 Post Locations and Reveal Height

There are two common design approaches for how posts connect to the torque tube via a bearing. These result in different post locations relative to the modules.

Some designers prefer to use the low-profile bearing shown in Figure 3 that sits underneath the solar modules. Low-profile bearings must be far enough from the module rail connection to the tube to avoid interference, but must also avoid the center of a module's width, where module deflection is greatest.

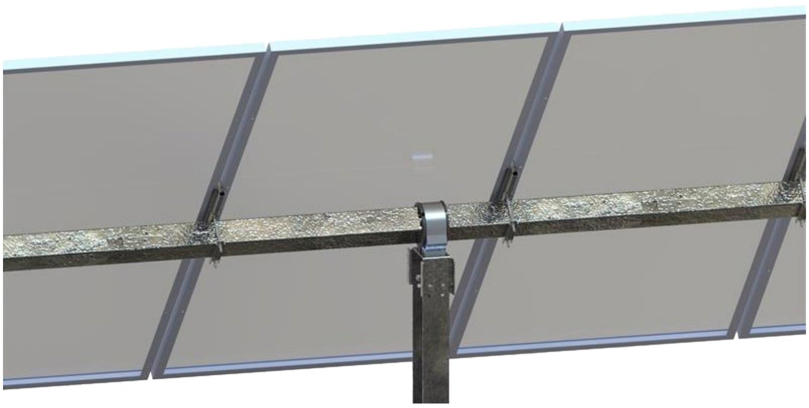

FIGURE 3:

Low-profile bearing installed underneath modules.

Other designers prefer to use the high-profile bearing shown in Figure 4, which sticks up above the glass of the PV modules. High-profile bearings must be between two modules with a gap to prevent the bearing from hitting the module glass and shading the adjacent module to the North.

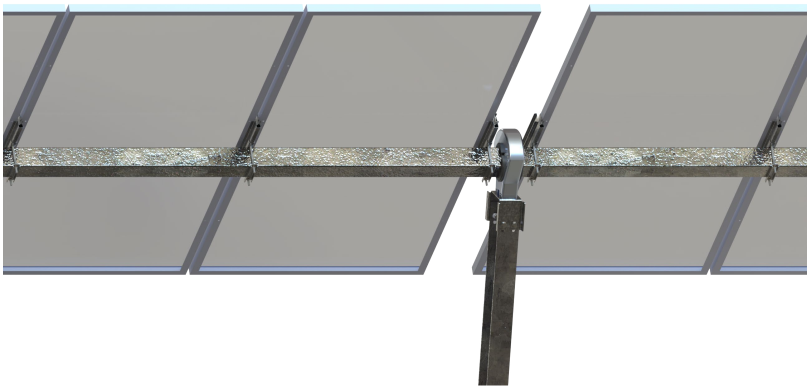

FIGURE 4:

High-profile bearing installed between modules.

In the event of a module change, the low-profile design is preferable, as it offers a broader range of acceptable bearing locations in relation to the module. The high-profile bearing needs to be at a specific distance between two modules, which could create challenges if module width or spacing changes.

For post reveal, changing to a longer module, e.g., from a 2.1 m long module to a 2.3 m long module, will result in either a decrease in minimum module clearance or a reduction in vertical tolerance in post installation.

2.5 Torque Tube Segment Length and Splice Locations

Most commercially available single-axis solar trackers have torque tubes that are shipped in smaller segments that are then connected on site. These connections typically utilize either a swaged end or splice plates. The locations of these tube segment connections must avoid geometric conflicts with bearings and mounting rails.

If the PV module on a project changes, the new design must be checked to ensure these geometric conflicts with the tube connections do not occur with the new module width or spacing. If conflicts are identified, tube segments must be recut on site to avoid these conflicts, increasing the financial impact of a module change.

Splice plate designs interact with torque tubes in a range of ways, from friction connections to bolted connections through the tube. Additional hole punches or post-processing requirements for bolted splice plate designs may further increase the financial impact of cutting tubes on site. Splice plates that connect to the tube through friction are preferable for module flexibility, as they do not require post-processing if the tube is shortened or lengthened.

2.6 Genius Tracker™ Structural Design

GameChange Solar's Genius Tracker system incorporates solutions for each of the structural considerations identified in Figure 5 to maintain flexibility through the design and installation process.

For module rails, the Genius Tracker system uses both clamp and purlin solutions. The SpeedClamp™ system connects directly to the module frame, bypassing any difference in mounting hole locations. For modules of a similar width, SpeedClamps allow for consistent module spacing, mounting configuration, and overall table length, even for modules with varying mounting hole locations.

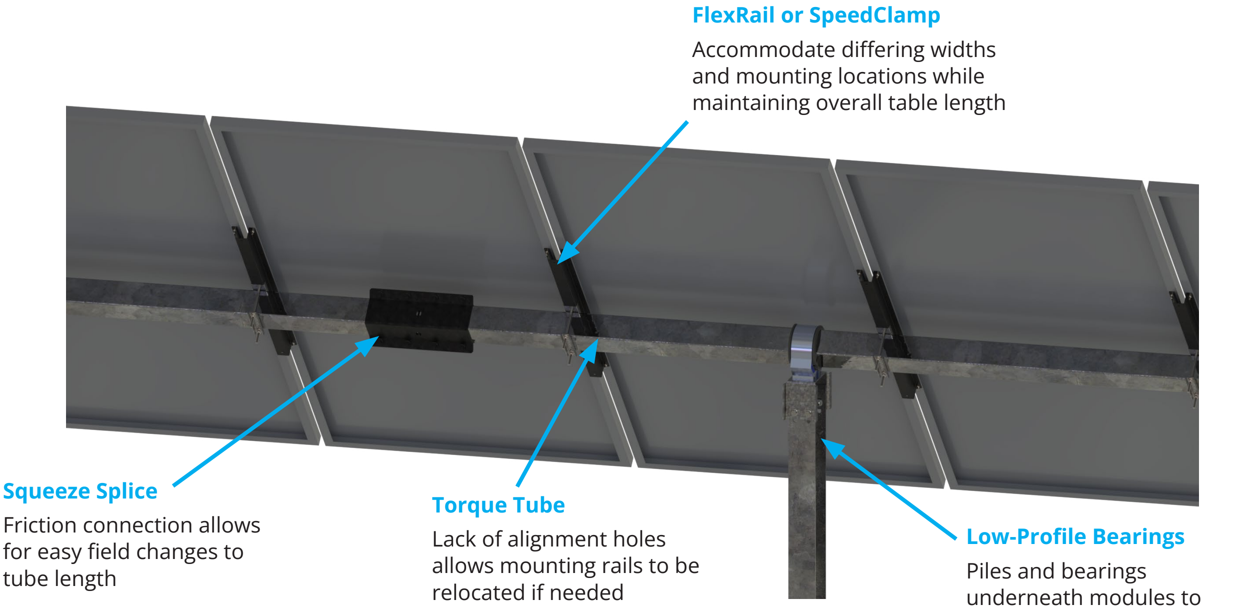

FIGURE 5:

Flexible design integrated into the Genius Tracker system.

The Genius Tracker system can use the FlexRail™ shown in Figure 6, which includes tolerance for differences in module width and mounting hole locations. By widening the mounting slots and punching multiple sets of slots, these purlins can maintain the same overall table length while mounting modules within a +/- 10 mm width and mounting hole variation window.

These two tools are highlighted in Case Study #1, where multiple modules can be mounted on the same Genius Tracker design using either the SpeedClamps or FlexRails.

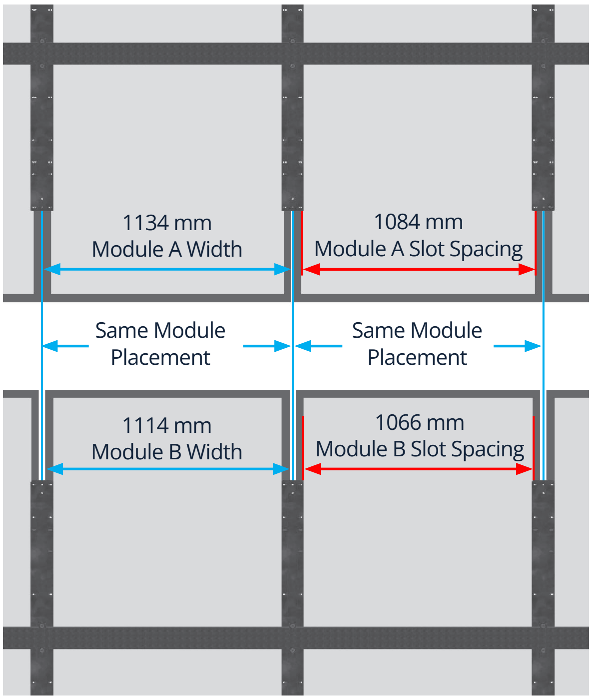

FIGURE 6:

Modules of differing sizes mounted on FlexRails, with the same on-center spacing and purlin placement, resulting in the same overall table length.

Even if the module change is so significant as to exceed the flexibility of the SpeedClamp and purlin systems, the Genius Tracker system's torque tube design and pile placement reduce the impact of any resulting structural conflicts.

Significant module changes may result in different mounting rail locations and overall table length. Because the Genius Tracker system's torque tubes do not include alignment holes, the mounting rail locations can be repositioned freely without additional hole punches.

Once the mounting rails are repositioned, geometric conflicts with the bearings must be checked. Because the Genius Tracker system employs a low-profile bearing, the increased positional tolerance described in Section 2.4 applies.

Suppose all this positional and dimensional tolerance is insufficient to avoid redesigning of the system or field remediation. In that case, the Genius Tracker system's torque tubes are easy to field cut to a length that works for the new module configuration. The torque tubes do not include mounting rail alignment holes, splice connection holes, or any other punches. Because they are unpunched tubes, the Genius Tracker torque tubes can be more efficiently cut or spliced together as needed in the field.

Figure 5 above highlights each of these redundant levels of flexibility in the Genius Tracker system. Together, they create an effective means of mitigating costs due to module changes starting at the design stage, all the way through installation.

3.0 Module Selection Before Production

The impact of a module change will vary greatly, depending on when the final module is selected. While module changes can be accommodated at any stage, the likely impacts for each stage are discussed in detail below.

3.1 Module Selection Before Production

This design and installation process is the most straightforward and economical. The PV module is selected before the fabrication of any tracker components, and therefore all tracker components are optimized for that given PV module. This includes the tracker length and layout of the power plant, all of the module rails, module rail to torque tube connections, torque tube segment lengths, and post locations.

This scenario also includes the design processes in Case Study #1 and Case Study #2 below, where the tracker is designed for a few select PV modules prior to production. While the trackers are not flexible for any potential module, they are designed to be installed with any module from a select list while minimizing upfront and field-remediation costs.

Although this option will result in some extra tracker cost to accommodate the variety of modules needed, this up-front financial penalty is often much less than what it may cost to change modules later in the design and installation process.

3.2 Module Selection Before Post Installation

In this scenario, all tracker parts have been produced assuming a specific PV module, but no parts have been installed. The critical advantage to selecting a PV module at this point versus later in the design process is the ability to optimize the location of the posts in the power plant. Posts can be relocated to maximize post-to-post spacing, thereby minimizing the post count per tracker table without creating geometric conflicts with mounting rails. Posts can also be positioned to avoid conflicts with tube segment connections, thereby minimizing the number of tube segments that need to be cut to length on site. When switching to larger modules or longer tracker tables, more posts may still be required for each tracker table, resulting in both financial and lead time impacts.

Because all module mounting rails have already been produced, there may be impacts on the mounting rails. If the project uses a purlin connection, the purlins may need to be replaced or field drilled to accommodate the new module's mounting hole location. While it is likelier that a clamp system will work for the new module without modification, the mechanical capacity of the PV module, given the existing clamp type and clamp length, must be checked against the site-specific loads.

Depending on module geometry, specific tube segments on each table may need to be cut to a new length to avoid geometric conflicts with bearing assemblies and mounting rails.

3.3 Module Selection After Post Installation

As expected, PV module changes at this stage of installation are the most difficult and typically the costliest. It is likely that the new PV module, with a different width or spacing, will result in geometric conflicts between a mounting rail and the installed post and bearing assembly. This issue can be resolved by stopping module installation one module short of the conflicting bearing assembly, then installing the next module, shifted down the tube enough to avoid interfering with the bearing, as illustrated in Figure 7. While this option has been successfully used to allow for changes in PV module selection after the posts are installed, like in Case Study #3 below, it results in a lower module density and an additional cost of one mounting rail for each occurrence.

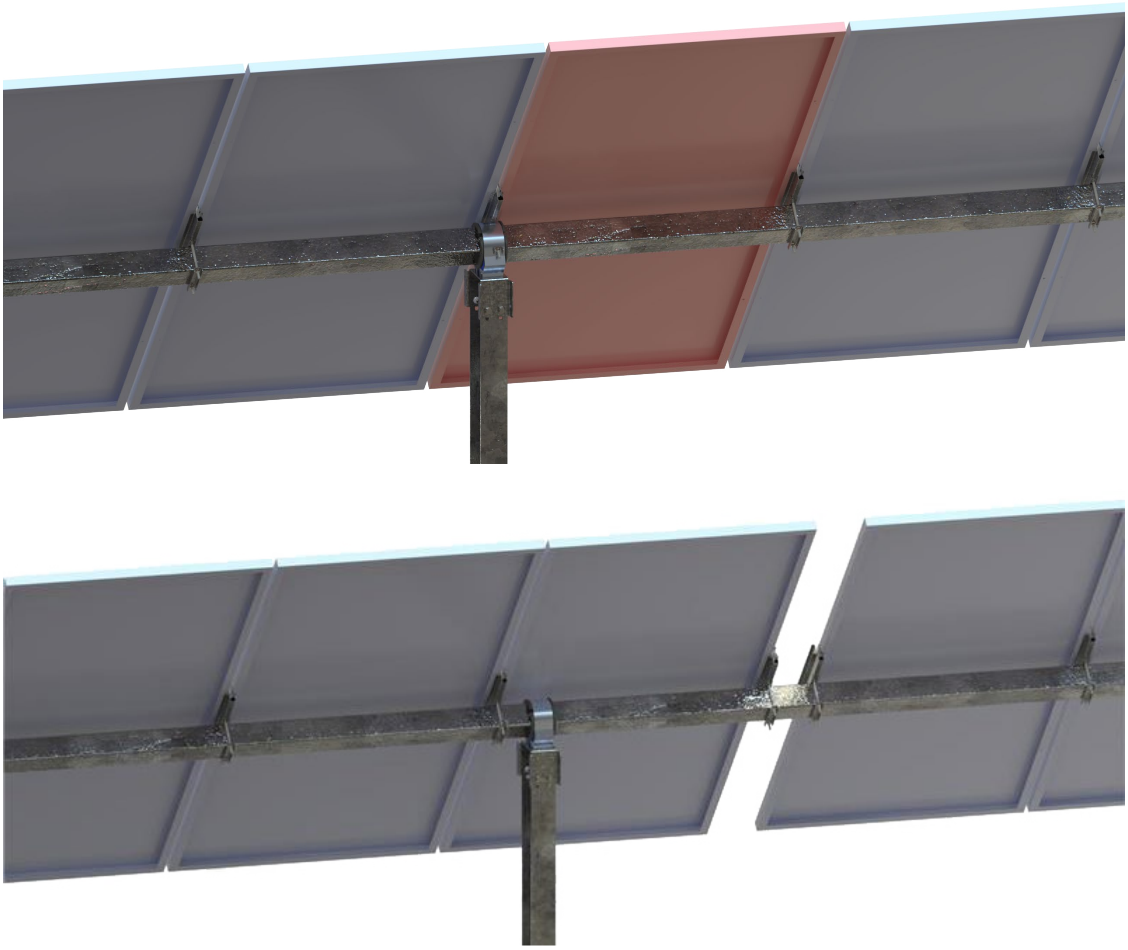

FIGURE 7:

The module in red would conflict with the bearing, so a gap is created such that the purlin of the conflicting module is shifted down the tube, away from the bearing.

All concerns raised in Section 3.2 regarding the impact of table length, mounting rail compatibility with the new module, and cutting torque tubes to length to avoid geometric conflicts must all be considered in this scenario.

4.0 Case Studies

4.1 Case Study 1: Designing for Multiple Modules

Case Study #1 is for a proposed project in Florida. The developer for the project is considering between modules with the following characteristics. All modules utilize the same string size and strings per table. This analysis is being performed during the design phase, before any material is produced.

Module Manufacturer	Vendor A	Vendor B	Vendor C	Vendor D
Module Length (mm)	2266	2384	2264	2384
Module Width (mm)	1134	1114	1134	1133
Module Slot Spacing Length (mm)	400/990/1400	400/1100/1400	400/1100/1400	400/790/1400
Mounting Slot Spacing Width (mm)	1084	1066	1084	1091

Because these modules are all of a similar width, the flexible mounting rail options can be used to eliminate any difference in module spacing, mounting rail location, and table length. Based on the project loading and mechanical capacities of these modules, there are two mounting rail options: SpeedClamp or FlexRail.

For moderate and low wind speed sites, SpeedClamps bypass all mounting hole variation, resulting in the same module spacing and thus overall table length. The 1 mm difference between Module A module width and all others only amounts to less than 1 cm [0.4 in] difference in overall table length. This minor variation can be accommodated with a small amount of tube length provided to cover the scenario where the wider modules are installed.

For high wind speed sites, FlexRails allow for consistent module spacing and thus overall table length, despite the variation in mounting slot locations. To account for the variety of mounting slot spacings in the length direction, 400 mm, 790 mm, 990 mm, 1100 mm, and 1400 mm slots are punched into the FlexRails in high wind loading sections of the site. When the final module arrives on site, the installer will bolt through whichever slots align between the FlexRail and the module. To account for the variety of mounting slot spacings in the width direction, the FlexRails have large slots running in the width direction that can account for +/-10 mm of variation. As described in Section 2.6 and shown in Figure 5, the FlexRails maintain module placement despite the relative movement of the mounting slots.

Under both mounting scenarios, all structural calculations are performed using the specifications of Module D because it is the longest and thus results in the highest loading.

With these minor design considerations, the Genius Tracker system can accommodate any module from this list without any field remediation or additional installation cost.

4.2 Case Study 2: Designing for Different Form Factors

Case Study #2 is for a proposed project in Texas. The developer for the project is considering between modules with the following characteristics. This analysis is being performed during the design phase, before any material is produced.

Module Manufacturer	Vendor A	Vendor B
Module Length (mm)	2384	2279
Module Width (mm)	1303	1134
String Size	30	27
Strings per Table	3	4

Because these modules have significant differences in width and quantity per table, the mounting rails are unable to absorb these design impacts, as seen in Case Study #1.

Due to the differing width and module quantity per table, Module B's design results in a table ~15 feet [4.5 m] longer than that of Module A. To accommodate this, the row tube design extends to cover the longer table length.

The differing module width also results in differing mounting rail locations between the two module designs. Due to the low-profile design of the Genius Tracker bearing, the post locations in Figure 8 can be identified that avoid conflict with mounting rails for both modules.

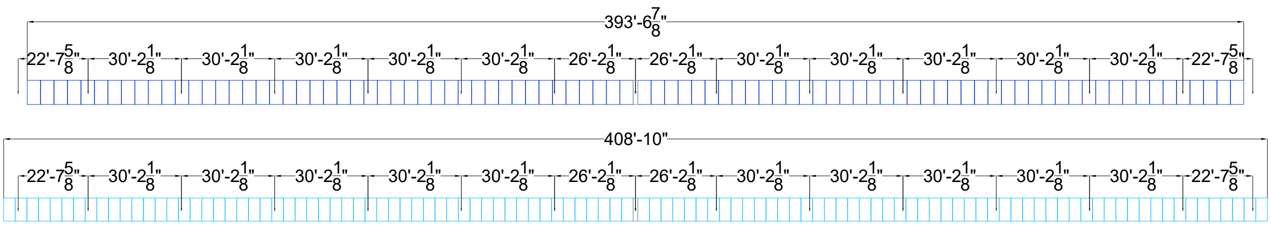

FIGURE 8:

Tracker designed to accommodate both modules.

As with Case Study #1, the mounting rails can be designed to accommodate varying mounting hole locations. All structural calculations are performed using the table length from Module B combined with the module length from Module A to account for the highest loading scenarios.

Though these impacts are larger in scale than Case Study #1, they still result in a Genius Tracker system capable of accommodating either vastly different module.

Depending on the timing of module selection, the design can be further optimized. For example, if Module A is selected prior to post installation, the northmost and southmost posts can be installed under the last module to increase aisle size for improved access.

4.3 Case Study 3: Changing Modules after Tracker Installation

Case Study #3 is for a project in California where the tracker structure, including posts and torque tube, was installed prior to a module change. The developer for the project changed from Module A to Module B with the following characteristics. Both modules utilize the same string size and strings per table.

Module Manufacturer	Vendor A	Vendor B
Module Length (mm)	2117	2094
Module Width (mm)	1052	1038
Mounting Slot Spacing (length in mm)	400/1300/1600	400/990/1300
Mounting Slot Spacing (width in mm)	1016	997

This project is installed with SpeedClamps, which allows the design to bypass the variation in mounting slot spacings.

The new module is 0.55 in [14 mm] narrower than the module in the original design. This results in several geometric conflicts between the locations of the driven posts and the mounting rails to support the new modules. To accommodate this, module installation is stopped one module short of the bearing assembly. A gap is then created, and the next module is installed farther down the tube to prevent bearing interference, as described in Section 3.3 and illustrated in Figure 7. At each of these gaps to avoid a bearing, one additional SpeedClamp is required.

It is worth noting that if this project were originally designed with FlexRails with punches for the

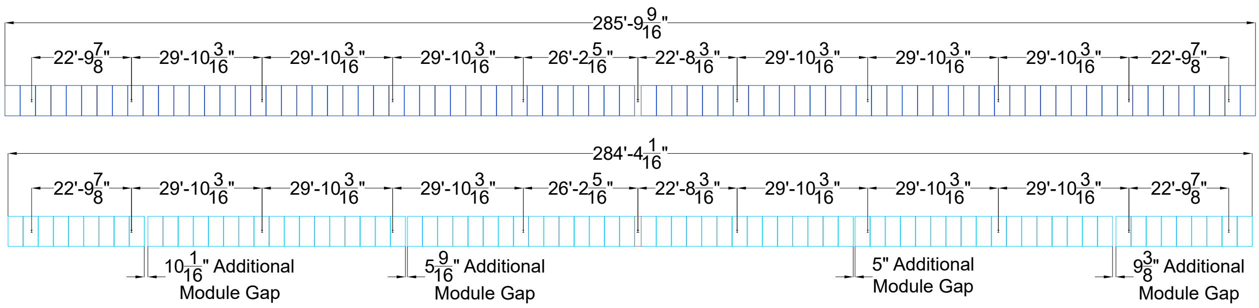

FIGURE 9:

Original table (above) and new table (below) utilize the same post quantity and spacing.

mounting holes of both modules, as opposed to SpeedClamps, this 0.55 in [14 mm] could have been absorbed by the increased tolerance in the rails. That same module change would have required no field remediation or gaps in the system.

Even with these gaps, as shown in Figure 9, the ultimate table length is slightly shorter than the original length. This allows for module mounting without additional torque tube material to extend or rework the tables.

5.0 Conclusion

These case studies demonstrate how FlexRails, SpeedClamps, and the inherent flexibility built into the Genius Tracker system help reduce costly rework associated with module changes. The features can be used at any project stage, from generating a single tracker design that supports multiple modules of differing dimensions to minimizing field work due to last-minute changes.

To maintain project timelines and budgets amidst an increasingly volatile module supply chain, developers, EPCS, and investors must consider flexibility when procuring and installing single-axis tracker systems.

The Genius Tracker is designed with superior module flexibility compared to standard trackers. FlexRail™ and SpeedClamp™ offer flexible module mounting for any loading scenario, while competitors rely on low-adjustment purlins that limit adaptability. Its un-punched torque tube enables variable alignment, unlike locked-in alignment holes that constrain module adjustment. The low-profile bearing assembly reduces geometric conflicts, and the adjustable friction squeeze splice provides a more adaptable connection than traditional bolted joints. Together, these features deliver increased flexibility for module changes while maintaining structural strength and long-term performance.

Tracker Feature	Genius Tracker™	Standard Trackers
High Load Mounting Rails	FlexRail™	Low-Adjustment Purlins
Moderate Load Mounting Rails	SpeedClamp™	Low-Adjustment Purlins
Torque Tube to Rail Connection	Un-Punched Tube	Locked-In Alignment Holes
Bearing Assembly	Low-Profile	High-Profile
Squeeze Splice	Adjustable Friction Connection	Bolted Connection

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